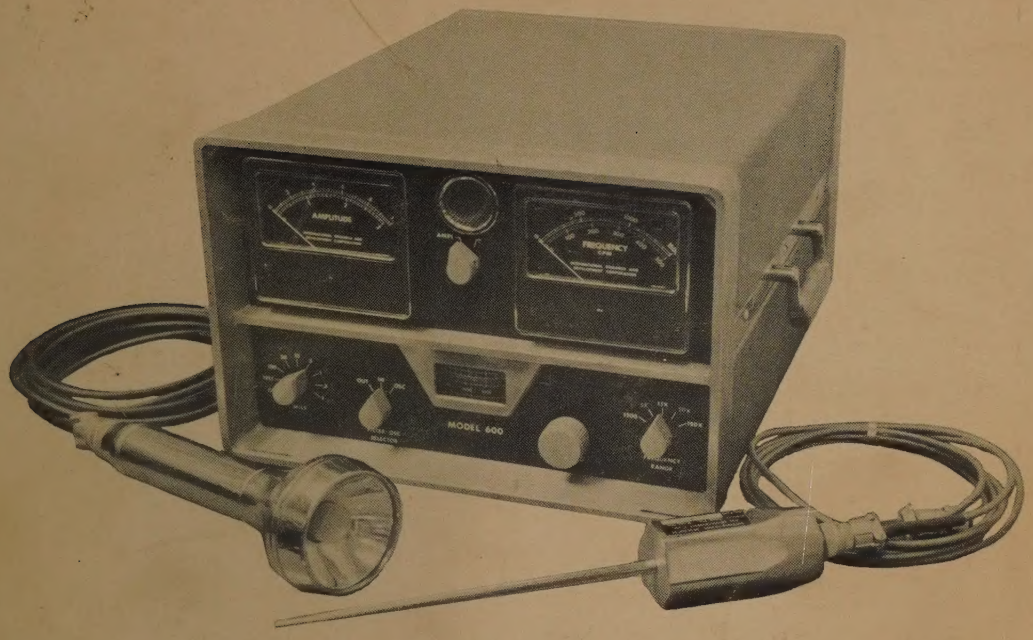


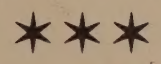
OPERATION AND MAINTENANCE

MANUAL

IRD

VIBRATION ANALYZER MODEL 600

International Research and Development Corporation is making available to industry electronic tools for practical and economical solutions of vibration and balancing problems. Our engineering and research departments are constantly developing new tools and instruments to solve other industrial problems through the science of electronics, though problems of dynamic balance and vibration elimination in industry are our first concerns.

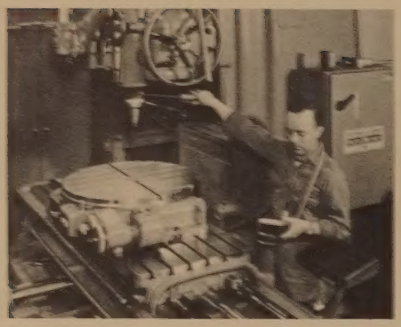


WARRANTY

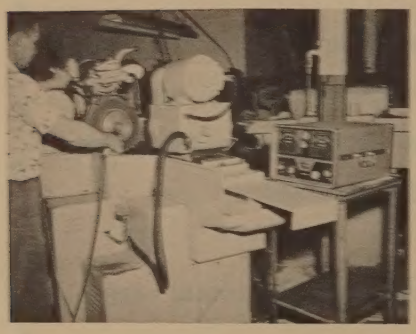
International Research and Development Corporation warrants that each unit is free from defects in materials and workmanship. Any new unit that is returned to our plant during the first year of use will be given any necessary repairs at no charge except shipping costs.

This warranty does not apply if the unit is subjected to abnormal usage.

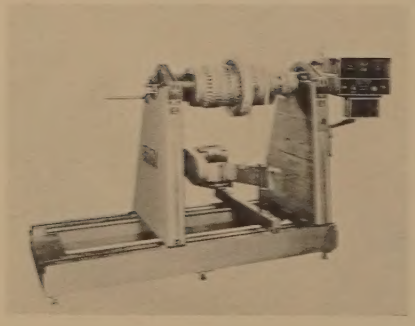
IRD SYSTEMS at work in industry



CHECKING - Jig Boring machine is inspected with Model 305 to check for an acceptable or not acceptable vibration level - the key to its efficient operating condition.



TROUBLESHOOTING - Once the 305 establishes the presence of high vibration, a vibration analyzer and portable balancer such as Model 600 above, is brought in to pinpoint the cause and correct it - without costly dismantling of machinery.



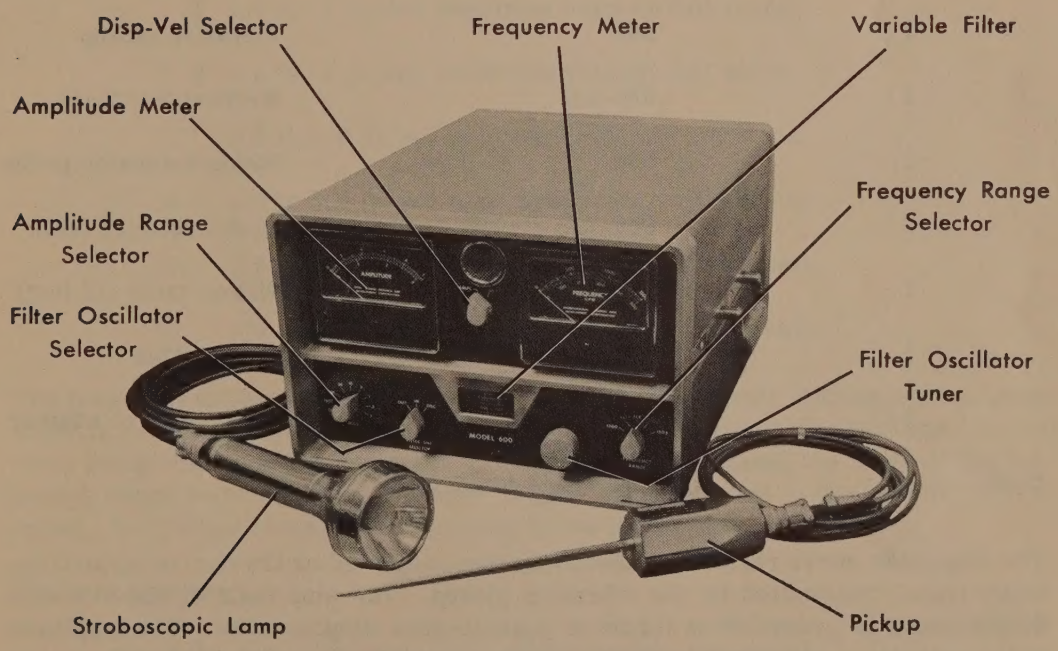
IRD DYNAMIC BALANCING SYSTEM - When it is required to balance a disassembled component such as the above rotor, the portable analyzer is a part of a complete dynamic balancing system. Above, IRD Vibration Analyzer is used in conjunction with Model 102 Dynamic Balancing System.

IRD

MODEL 600
Vibration Analyzer

INTRODUCTION

IRD Model 600 Vibration Analyzer constitutes a rugged, accurate and reliable instrument designed to perform three basic functions, namely to detect and measure vibration, to pinpoint the cause, and to correct imbalance, either in-place in conjunction with a machine assembly constituting a balancing machine. Furthermore, this instrument affords versatility, sensitivity, and simplicity of operation required to solve vibration problems of a wide variety.



DESCRIPTION

Model 600 Vibration Analyzer affords the three parameters required to analyze a vibration, namely displacement or velocity, frequency, and phase. Therefore, the instrument includes a displacement-velocity amplitude meter, a frequency meter, a vibration pickup, and a stroboscopic lamp. A variable electronic filter is included to increase the flexibility of the instrument. The associated controls appearing on the front panel are a displacement-velocity selector, an amplitude range selector, a filter-oscillator selector, a filter tuner, and a frequency range selector.

The general specifications of the instrument are:

Size:	9-1/2" x 15" x 18"
Weight:	37 lbs.
Power requirements:	105 to 130 volts, 60 cycles, 2 or 3 wire, 75 watts

The major components included in the standard unit are:

Quantity	IRD Type No.	Description
1	600	Instrument console
1	545	Vibration pickup
1	565-AN	Stroboscopic lamp
1	564	Pickup extension probe
1	600-72	Strob cable (12 feet)
1	565-4-12-2AN	Pickup cable (12 feet)
1	1065-11-8	Power cable
1	578-LS	Rodale 2-wire adapter
Fuse:	3AG 1-1/2 Amp. Slow-Blow	

The amplitude meter registers selectively the integrated or the non-integrated velocity signal transmitted by the vibration pickup. The amplitude of the vibration displacement is presented in terms of peak-to-peak displacement. The amplitude of the velocity is presented in terms of maximum velocity. The face of the meter is divided into two scales, the top scale being graduated from 0 to 1 by ten increments, the lower scale being graduated from 0 to 3 by three increments. The range selector permits the use of four ranges for the top scale, and three ranges for the lower scale.

These ranges are:

Displacement:

.1 = 0 to 0.1 mil peak-to-peak displacement full scale;

.3 = 0 to 0.3 mil peak-to-peak displacement full scale;

1. = 0 to 1.0 mil peak-to-peak displacement full scale;

3. = 0 to 3.0 mils peak-to-peak displacement full scale;

10. = 0 to 10. mils peak-to-peak displacement full scale;

30. = 0 to 30.0 mils peak-to-peak displacement full scale;

100. = 0 to 100.0 mils peak-to-peak displacement full scale.

One mil equals one thousandth of one inch.

Velocity:

.03 = 0 to .03 in/sec maximum velocity full scale;

.1 = 0 to .1 in/sec maximum velocity full scale;

.3 = 0 to .3 in/sec maximum velocity full scale;

1. = 0 to 1.0 in/sec maximum velocity full scale;

3. = 0 to 3.0 in/sec maximum velocity full scale;

10. = 0 to 10.0 in/sec maximum velocity full scale;

30. = 0 to 30.0 in/sec maximum velocity full scale.

The frequency meter indicates the number of times per minute that the system under study is vibrating. This meter has two scales to facilitate the readings, the top scale being white and the lower scale being yellow. To change the range of the frequency range selector which has white ranges corresponding to the top scale on the meter, and yellow ranges corresponding to the lower scale.

These ranges are:

1.5 = 0 to 1500 cycles per minute (white, top scale)

5. = 0 to 5000 cycles per minute (yellow, lower scale)

15. = 0 to 15,000 cycles per minute (white, top scale)

50. = 0 to 50,000 cycles per minute (yellow, lower scale)

150. = 0 to 150,000 cycles per minute (white, top scale)

The continuously variable filter broadens the versatility of this instrument. It simplifies complex vibration and balance problems on assembled machines by filtering all frequencies other than that to which it is tuned. The dial of the filter is divided: the top scale is white, and the lower scale is yellow, corresponding to the color coding of the frequency range selector and the frequency meter (the frequency range selector applies to the filter as well as the frequency meter).

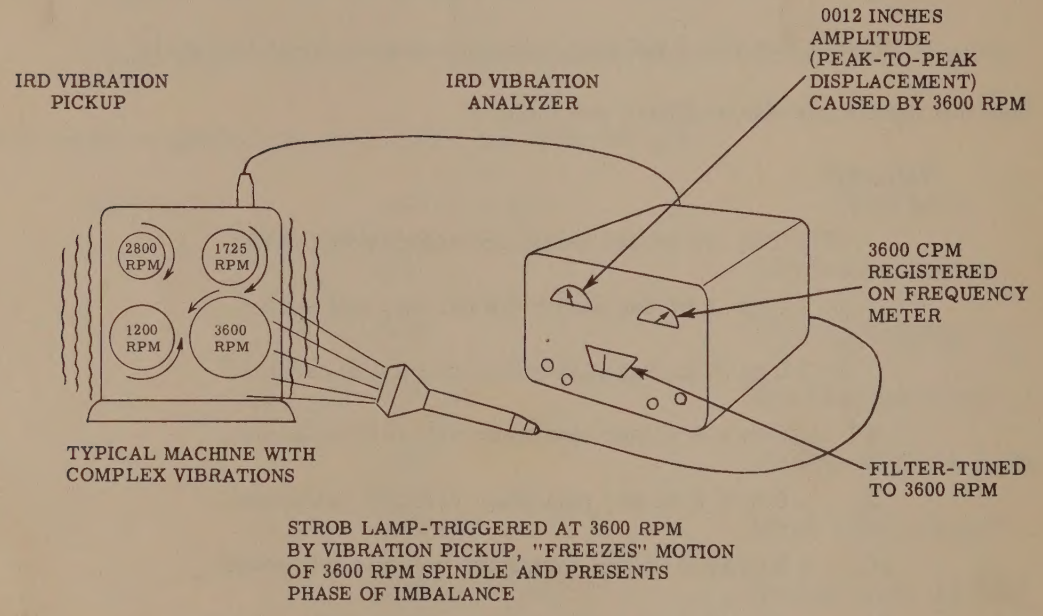

IRD VIBRATION PICKUP
IRD VIBRATION ANALYZER
0012 INCHES AMPLITUDE (PEAK-TO-PEAK DISPLACEMENT) CAUSED BY 3600 RPM
2800 RPM
1725 RPM
1200 RPM
3600 RPM
3600 CPM REGISTERED ON FREQUENCY METER
TYPICAL MACHINE WITH COMPLEX VIBRATIONS
FILTER-TUNED TO 3600 RPM
STROB LAMP-TRIGGERED AT 3600 RPM BY VIBRATION PICKUP, "FREEZES" MOTION OF 3600 RPM SPINDLE AND PRESENTS PHASE OF IMBALANCE

Figure 1 - Illustration showing how variable filter is tuned to one component only.

The oil-damped vibration pickup (inductive velocity type, IRD Model 545) is a rugged unit designed to withstand the rigors of industrial usage without impairment to calibration or sensitivity. The pickup responds only to vibration in the direction of the probe (transverse response is less than 5% below 100 cps). A 12 foot pickup cable is provided with each unit (longer lengths are available). A detachable extension probe is also provided with the pickup.

The specifications of the vibration pickup are:

Dimensions:

2-1/4" diameter by 5-5/8" length (including connector)

Threads for the extension probe:	1/4-28 x 1/4 N. F.
Weight:.	20 ounces
Temperature range:.	60^{o} F. to 110^{o} F case temperature
Sensitivity:.	Approximately 1160 millivolts per inch per second Approximately 260 millivolts RMS at .001 inch peak-to-peak displacement at 100 cps.

Longer pickup cables are available as follows:

Length	IRD Type No.
25 feet	565-4-25-2AN
50 feet	565-4-50-2AN
75 feet	565-4-75-2AN
100 feet	565-4-100-2AN

The stroboscopic lamp is housed in a flashlight-type case. A push button switch is incorporated on the case to actuate the stroboscopic bulb (IRD type 565-14) may be replaced by unscrewing the shield at the front of the case. Although the stroboscopic lamp is normally triggered by the vibration (for purposes of measuring relative phase of vibration caused by imbalance in a rotating component, and for locating the cause of vibration), it can also be manually controlled through a range of 450 to 5000 flashes per minute. The controls used for the filter are also used for manual strob control, and only the 1.5 and 5. ranges are used to indicate the flash rate.

A scope jack and recorder jack are provided at the rear of the instrument; the first permits the visual study of the vibration waveform: the latter permits the graphic study of the vibration. The signal from the scope jack should be connected into a high impedance amplifier with an input impedance of at least one megohm; the scope jack provides an AC signal equivalent to approximately 17 volts RMS at full scale indication on the amplitude meter.

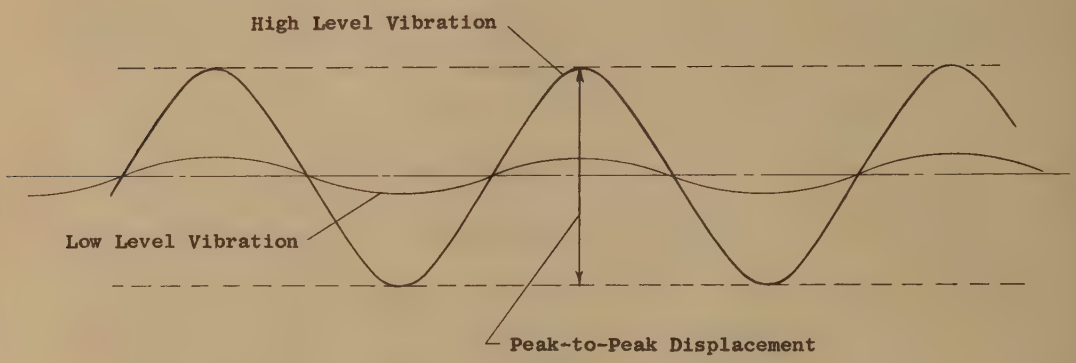
The signal from the recorder jack should be connected to a recorder through a preamplifier with an input impedance of at least 50,000 ohms; the recorder jack pro-

vides a DC signal equivalent to approximately 1 volt at full scale indication on the amplitude meter.

A 117 volt, 60 cycle, 2 wire accessory outlet is available at the rear of the console for operation of supplementary equipment.

OPERATION

The IRD Model 600 Vibration Analyzer is designed to measure the peak-to-peak displacement and maximum velocity of vibration and pinpoint the source. When imbalance is the cause, it serves to balance the rotating parts in-place, without costly dismantling of machinery. The instrument also serves as the electronic brain of dynamic balancing systems used in plant maintenance and production for dynamic balancing of components prior to assembly.



The basic principle of the electronic operation of this instrument is as follows:

> The vibration pickup transforms the mechanical vibration being observed into a corresponding electrical signal whose voltage is directly proportional to the amplitude of the vibration. This signal is then amplified in the electronic circuit and registered on the amplitude meter and on the frequency meter. The variable filter, when used, eliminates all other frequencies of vibration except that to which it is tuned. The signal from the pickup also normally triggers the stroboscopic lamp in synchronization with the frequency of the vibration (an internal oscillator is also incorporated with which the flash rate of the lamp can be manually controlled if desired).

To prepare the Vibration Analyzer for operation, follow these steps:

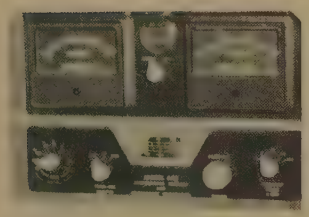
Step 1 - Connect the power cable to a 117V, 60 cycle outlet and to the receptacle at the rear of the instrument.

Step 2 - Screw the probe to the pickup and connect the pickup to the console by means of the cable provided.

Step 3 - Connect the stroboscopic lamp to the console by means of the cable provided. The connector at the console end of the cable is of the lock-on type and is attached by pulling back the outside connector barrel and attaching the cable to the console.

Step 4 - Turn on the instrument by turning the amplitude range selector switch from the OFF position.

The instrument requires five to ten minutes warm-up period for optimum operation.



Step 5 - Set amplitude range selector to TEST position; set frequency range selector to 5 position with filter out. The amplitude meter should read approximately - half scale, and the frequency meter should read 3600 cpm. These values have been preset to determine if the instrument is working properly. The filter can be switched IN and the tuning of the filter checked at 3600 cpm.

To operate Model 600 Vibration Analyzer, follow these steps:

Step 1 - Place the vibration pickup at the locations where the vibration is to be measured or analyzed.

Step 2 - The DISP-VEL selector is normally used in the DISP position.

Step 3 - Set the amplitude range selector to the least sensitive range (100); if the meter indicates less than 30 mils, change ranges until you obtain an up-scale reading.

Step 4 - Set the frequency range selector to the desired range.

Step 5 - Set filter control to OUT position or IN position as required.

The IRD Model 600 Vibration Analyzer serves three purposes, namely to measure vibration, to pinpoint the cause, and to correct imbalance inplace. When a component requires to be balanced in a balancing machine (IRD Model 102), the analyzer serves as the electronic brain of the machine.

MEASURE VIBRATION - Any machinery having rotating components has a certain amount of vibration. When it becomes excessive, this vibration will cause undue wear to the machinery. To remedy this situation, the vibration must be periodically measured to assure that it is within tolerances.

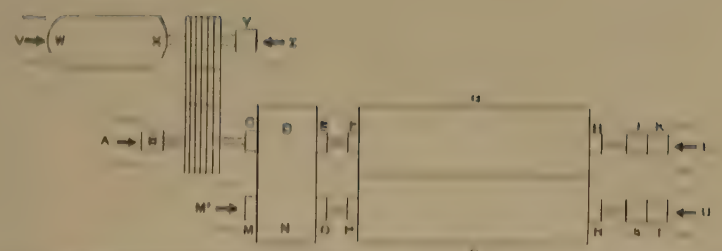
This is effected by measuring the overall vibration, and the vibration of each component in the machinery. The readings obtained can be recorded on charts such as figure 3. This chart includes the reading positions, the space to record displacement, frequency, and when available, the manufacturer's vibration tolerances. Each time readings are taken, they are recorded and compared with previous readings.

PINPOINT THE CAUSE - Once the instrument has determined that excessive vibration exists, the next step is to pinpoint the cause, or to troubleshoot the machinery. The following are the steps to be taken to pinpoint the cause of vibration. These are not necessarily in their order of importance because each individual problem requires its own order of steps.

1 - Determine the nature of the difficulty on the equipment involved; find out how long the trouble has been occurring, whether any changes were made in the equipment which may have precipitated the trouble, and whether or not any steps have been taken in an attemp to correct the trouble.

2 - Become familiar with the equipment by making a thorough examination of its component parts; determine the approximate speeds involved in the rotating components associated with the equipment. Place reference chalks marks on rotors, belts etc.

3 - Measure the background vibration at the critical points on the equipment with the equipment completely shut down. This is the lowest level of vibration which can be attained on the equipment by taking corrective measures within the equipment itself; in the case of precision equipment such as precision machine tools the principle source of trouble is quite often transmitted vibrations from exterior sources and very little difference will be detected in the level of vibration with the machine running and the machine shut off completely. In any event, if the Vibration Analyzer detects the major source of the transmitted vibration, note this for future correction of the difficulty.



LOCATION

BLOWER SERIAL NO.

DATE TESTED

HAND (L) (R)

STD. FILTER

V = VERTICAL PROBE

H = HORIZONTAL PROBE

DATE BUILT

DATE INSTALLED

TESTED BY

F = FREQUENCY

V & H = VIBRATION AMPLITUDE IN INCHES

		EFF.	R.P.M.	AMP'S.		A	B	C	D	E	F	G	H	J	K	L	M	M'	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
TEST NO.	BLOWER NO.				V																										
					F																										
					H																										
					F																										
TEST NO.	BLOWER NO.				V																										
					F																										
					H																										
					F																										
TEST NO.	BLOWER NO.				V																										
					F																										
					H																										
					F																										
TEST NO.	BLOWER NO.				V																										
					F																										
					H																										
					F																										

REMARKS.

Figure 3 - Vibration Chart.

4 - Place the equipment into operation and again measure the vibration at the critical points. Determine the predominant cause of the vibration by relating the frequency of the vibration (filter out) to the various components and characteristics of the system under study; use the stroboscopic lamp to determine whether the vibration is in synchronism with any rotating or oscillating components with the system. In cases where many components in the machine are completely sealed and cannot be observed with the stroboscopic lamp, it is helpful to have available a blueprint of the equipment in order that the frequency of the vibration can be related to the speed of some interior component. For rotating components which are visible, the stroboscopic lamp can be used in the OSC position to determine the rotating speed and slow down the rotating motion for visual observation of the component while they are running.

5 - When the vibration is measured at the critical points on a machine, a condition will sometimes be observed in which a "beat" or unsteady frequency reading is obtained due to the presence of more than one predominant source of vibration. The amplitude reading is also unusually somewhat unsteady. With these indications, use the variable filter to determine the various frequencies of vibration present, and the causes of these frequencies. When tuning the filter, the following procedures are recommended:

a) Tune the filter carefully from lower to higher frequencies.

b) Always maintain some reading (about 10% to 15% of full scale) on the amplitude meter in order that there is sufficient signal available for indications to become apparent.

c) As the filter is being tuned, the presence of a measurable frequency component will be made known by observing that the frequency meter steadies to a fixed reading. When this is observed, tune to a peak amplitude indication.

6 - Correct the major cause of vibration and again measure the vibration at the critical points. Determine the remaining sources of trouble, if any, and correct these as required. The level of vibration to which the machine is corrected is dependent upon many factors, which may at times be (1) whatever level is necessary to obtain satisfactory operation from the machine, (2) a vibration level specified by commercial tolerances or established tolerances, (3) the background level beyond which the vibration level cannot be reduced without correcting sources of trouble outside the machine, (4) the lowest level which can be obtained without major redesign of the equipment, or (5) the level which has been proved to be satisfactory by previous experience.

NOTE: Do not try to compute the frequency of vibration by the number of images obtained when observing a reference mark on the rotating part. Use the frequency meter.

7 - In cases where there are many various components in a given assembly which can be operated separately, it is sometimes helpful to operate each component

one at a time in order to determine which component is the major contributor to the overall amplitude of the vibration; the analysis can then be simplified by operating this section of the machine separately and correcting the source of difficulty.

When using the stroboscopic lamp, it is important to remember that the flash rate of the lamp is not normally controlled by the operator, but by the vibration signal. However, when on OSC position, the lamp flashes are adjusted with the tuning knob until the part being studied appears stopped. The lamp then becomes a tachometer.

When using the unit as a stroboscopic tachometer, with the switch in the OSC position, adjust the flash rate of the stroboscopic lamp to its maximum rate (5000 flashes per minute) by means of the tuning knob. Slowly reduce the flash rate until the rotating part under observation appears to be stopped or frozen as a single image. Record this flash rate as R_1. Continue to reduce the flash rate until the part again appears stopped, being very careful not to miss any flash rate at which this occurs. Record this flash rate as R_2. The rotating speed may then be determined as follows:

$$RPM = \frac{R_1 \ R_2}{R_1 - R_2}$$

Example:

By following this procedure, it is determined that the rotating part is visually "frozen" at flash rates of 4000 flashes per minute and 3000 flashes per minute.

$$RPM = \frac{\text{4000 times 3000}}{\text{4000 minus 3000}} = \frac{12000000}{1000}$$

RPM = 12000 Revolutions per minute

In this example, the rotating part would also be "frozen" at flash rates of 2400, 2000, 1714, 1500, etc. flashes per minute (every submultiple of 12000 flashes per minute) and any adjacent pair of readings can be used to determine the speed. For instance, if the 2400 flashes/minute and the 2000 flashes/minute readings were used, the calculation would be:

$$RPM = \frac{\text{2400 times 2000}}{\text{2400 minus 2000}} = \frac{4800000}{400}$$

RPM = 12000 Revolutions per minute

Using the tuning control and the two lower positions of the frequency range selector, the flash rate can be varied from 450 to 5000 flashes per minute. The internal oscillator is not operative on the higher positions of the frequency range selector.

To measure the velocity amplitude of the vibration, set the DISP-VEL indicator to the VEL position. Velocity measurements are normally used to analyze very high frequency vibrations which have a very low and almost undistinguishable displacement, but a considerably evident velocity. Velocity measurements are normally more effective than displacement measurements for balancing at very high speeds.

There is a very useful feature incorporated in the Model 600 to facilitate tuning the filter to the speed of the rotating component. Identical circuitry is used for both the filter and the oscillator; if the oscillator is tuned such that the flashing rate of the strob lamp is in synchronization with the rotation, this procedure also tunes the filter to the proper setting.

Relative phase is measured when the strob lamp is being triggered by the signal vibration pickup by virtue of the fact that the strob light is not only triggered once for every cycle of vibration but also is triggered at one particular instant throughout the cycle. In other words, if a motor bearing is vibrating back and forth to the left and right in a lateral direction, and a keyway or reference mark on the motor shaft is being observed with the stroboscopic lamp, the angular position of the keyway or reference mark as observed when the pickup is applied to the left side of the bearing would be directly opposite or 180 degrees out of phase with respect to the angular position as observed when the pickup is applied to the right side of the bearing.

Typical vibration characteristics resulting from specific troubles are as follows:

1 - BEARINGS - A rough anti-friction bearing results in a relatively high frequency of vibration which is several times the frequency of the rotating member which is mounted in the bearing but not necessarily a direct multiple of that speed. The frequency reading is usually unsteady, and the amplitude reading may be somewhat unsteady also. The vibration due to a rough bearing of this type may be distinguished from high frequency electrical vibrations by virtue of the fact that the bearing vibrations will continue even after the electrical driving power is removed and the rotating member mounted in the bearing is coasting to a stop.

2. BEARINGS - An anti-friction bearing can cause vibration due to the fact that the inner and outer races possess a certain amount of angular misalignment. This vibration will occur primarily in the end-wise or axial direction with respect to the shaft which is mounted in the bearing and occurs at a frequency equivalent to the rotor speed.

3. NON-CONCENTRICITY - Lack of concentricity in an anti-friction bearing causes vibration which usually becomes apparent only at a low level of vibration when a precision degree of balance is being accomplished on the equipment which is running in the bearing. This may result in a vibrational frequency equivalent to the rotational speed of the part running in the bearing; the characteristics are such that it acts like an imbalance which shows up only in one radial direction (horizontal, vertical, or some other specific angle). The equipment can be balanced to a very low level with respect to

the vibration in one direction but will not possess a low level of vibration in another.

4. EXCESSIVE CLEARANCE - Conditions of excessive clearance within a sleeve bearing can be detected by the difference in the amplitude reading which is obtained on the bearing housing in comparison with the amplitude which is obtained by directly measuring the vibration on the shaft which is running in the bearing.

5. BELTS - Belt vibrations can be set up in which the frequency of vibration is equivalent to the rotational (not peripheral) speed of the belt or a multiple of the rotational speed. In such a case the stroboscopic lamp will "freeze" or "stop" a chalk mark placed on the belt, and "freeze" or "stop" the mark in one certain area or position or several positions in the event that the belt vibration is a multiple of the belt rotational speed. Belt vibrations are sometimes somewhat unsteady with respect to both amplitude and frequency, and are usually low in frequency due to the fact that the rotational speed of belt drives is usually low. In cases where a multiple belt drive is being used and several belts may be causing the overall vibration, the observation of one of the belts with the stroboscopic lamp may show a tendency to stop a mark on the belt in one given position (the mark would appear in one area of the belt more often than in other areas) rather than a fixed "stopping" of the belt.

6 - AERODYNAMICS - Aerodynamic vibrations may arise from several sources, such as (1) unequal pitch on the blades of a propeller-like system in which the axial force against one blade is not equal to the axial force against the remaining blades, resulting in a vibration which occurs at a frequency equivalent to the rotating speed and is primarily (but not totally) acting in the endwise or axial direction, (2) blade flutter may be encountered at the resonant frequency of the blades if there is some source of energy at that frequency to excite the blade or blades, and (3) duct work, shrouds, piping, etc., can be excited to resonance by the flow of air, gas, or liquid through the system.

7 - HYDRAULICS - Hydraulic vibrations may result from such causes as cavitation in pumps, vibrations excited by fluid flow, etc. Hydraulic systems are sometimes a source of troublesome vibrations on precision machine tools; this may be due to imbalance in the pumps, and is normally corrected by isolating the pump from the remainder of the machine.

8 - MECHANICAL - In practical vibration problems, a condition frequently arises in which the frequency of vibration is twice that of the rotating speed on a particular component which is being analyzed; this is usually referred to as a "double frequency" or a "double picture" (When the stroboscopic lamp is used to observe the rotating component, the vibration picked up by the pickup triggers the stroboscopic lamp twice for each revolution of the rotating part, and a reference mark appears to be stopped in two positions rather than one). This is usually an indication of some mechanical source

of vibration such as looseness, rubbing, wear, excessive play between mating parts, etc. One exception to this is the case of reciprocating components being driven from a crankshaft; in this case a "double frequency" arises naturally from the forces within the system.

9 - ELECTRICAL - Some types of vibration may be electrical in nature, such as case vibrations in transformers which are induced by the alternating electromagnetic fields. Another source of electrical vibration which is frequently encountered is torque pulses in single phase electrical motors; these result from the fact that the movement of the rotor throughout one revolution is not constant but consists of a series of jerks as the rotor passes each pole within the motor. This vibration occurs at synchronous frequency or some multiple of synchronous frequency.

10 - GEARS - Gears may be the cause of vibrations, the frequency of which is dependent upon the nature of the trouble and the character of the assembly in which the gear is mounted. For example, if tooth interference is taking place between two mating gears, the frequency of vibration on one gear will be equivalent to the product of the number of teeth on the gear and the gear speed in revolutions per minute. If a gear has a high tooth, the frequency of vibration will be equivalent to the product of the gear speed in revolutions per minute and the number of other gears with which the gear meshes.

11 - OIL WHIRL - In equipment which is designed to operate at a speed well above the shaft is running in lubricated sleeve bearings, a condition may arise in which "oil whip" may develop within the bearing and cause the shaft to "whirl" at a speed which is lower than the rotational speed. This "whirl" speed is often in the order of one-half the rotational speed, and the resultant vibration is approximately equivalent in frequency to one-half the rotation speed. This condition is usually corrected by altering the design of the bearing or changing the conditions of lubrication.

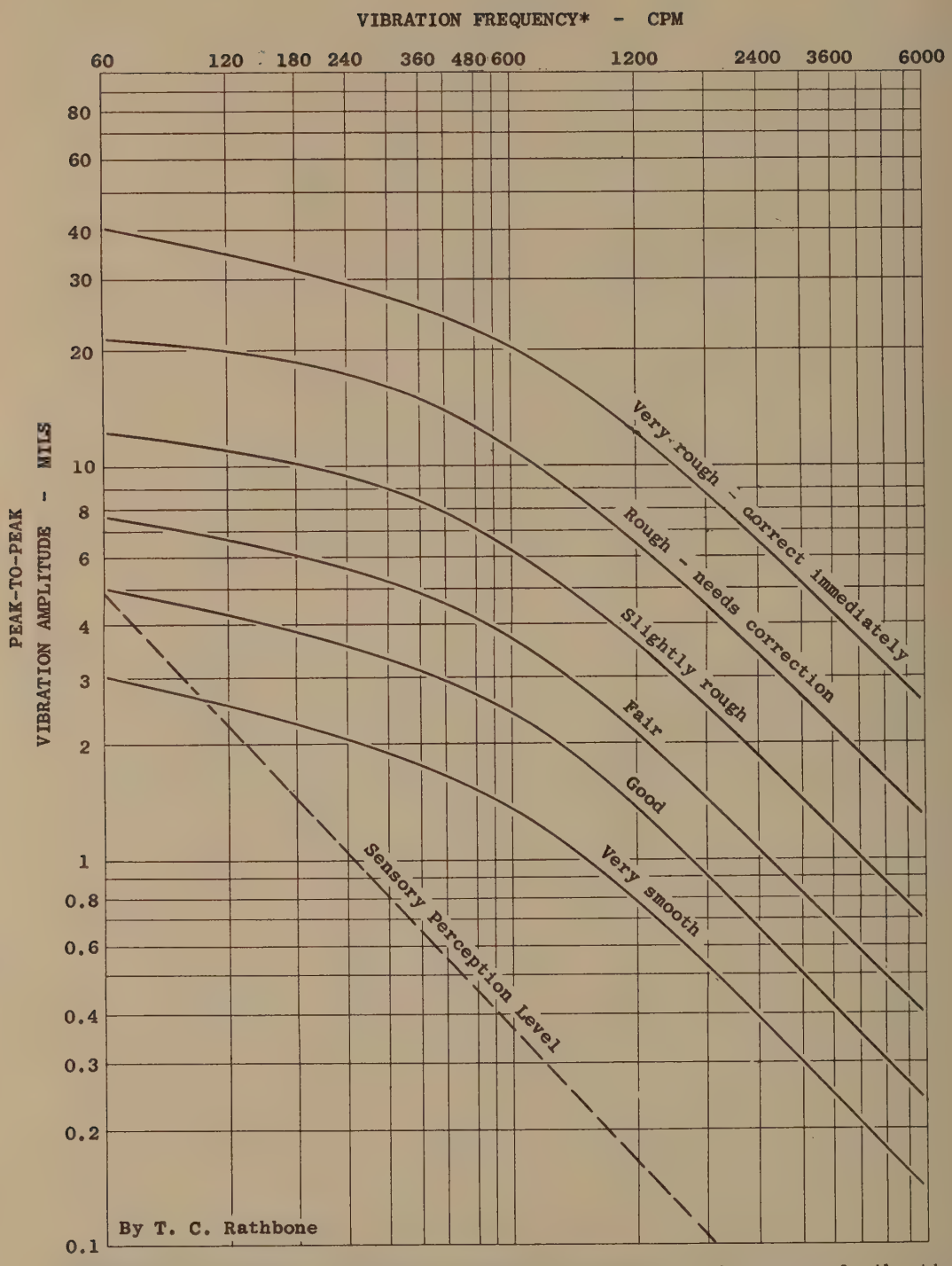
12 - RESONANCE - In some cases the reason that trouble is being encountered can be traced to the fact that system resonance is occuring at or near the operating speed of some component within the system, and vibrations which otherwise would be small are magnified. This can be detected by shutting off the power source and noting the manner in which the amplitude of vibration varies as the equipment coasts to a stop. By observing the amplitude and frequency readings while the equipment is slowing down, the frequencies can be noted at which the amplitude readings rise to a peak; these are the resonant or critical speeds. If the amplitude falls off very sharply as the equipment slows from operating speed, it is then apparent that the equipment is running near resonance. When this is the case, the amplitude of vibration can be reduced to a low level by (1) balancing to a high degree of precision the component which is exciting the resonance, or (2) modifying the system to change the resonance. Unless it is practical to obtain a precision balance and maintain it throughout the life of the equipment, some effort to change the resonance is usually warranted.

13 - MISALIGNMENT - Mechanical troubles such as misalignment or bent shafting can cause vibration difficulties. Since these conditions result in the rotating mass being displaced from its correct operating axis, the system may actually be out of balance although weight distribution within the part if not the primary source of trouble; the indications which result may be similar to those due to ordinary imbalance, but normal balancing procedures may not completely solve the trouble if the mechanical troubles are of a sufficiently major degree. Misalignment or bent shafts may result in a vibration frequency equivalent to twice the rotating frequency, resulting in a characteristic "double frequency" of vibration; the exact manner in which a misalignment will manifest itself depends upon the degree of misalignment, type of bearings, type of couplings, and equipment being used. It is recommended that the alignment always be checked if it is suspected as a source of trouble. This type of mechanical trouble often causes a high level of vibration in the endwise or axial direction on a bearing.

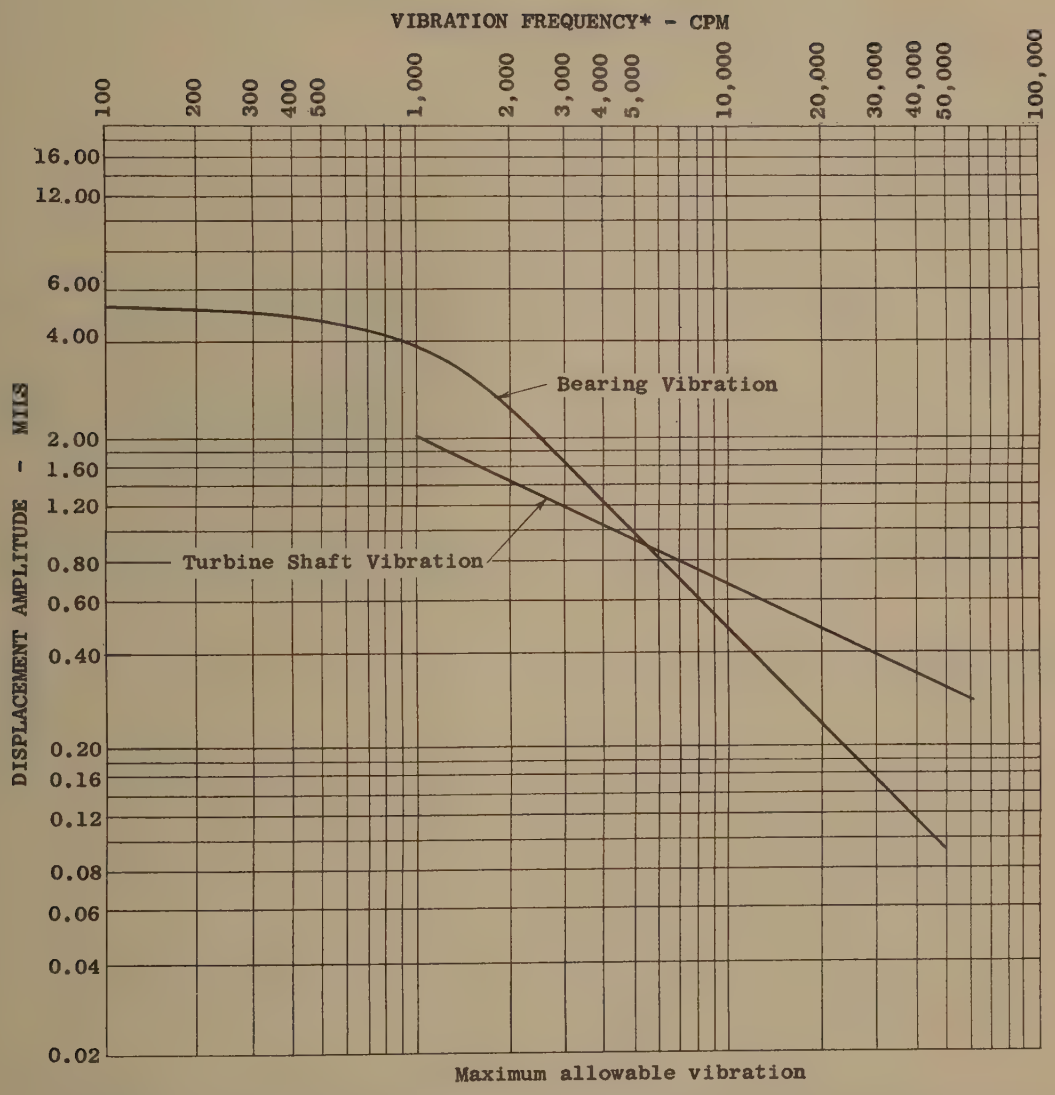
In cases where the shaft vibration should be measured, the pickup can be placed at the bearing points. However, if this is impractical, measurements can be taken by using a sharp-edged wooden probe such as the IRD PH-1 shaft stick. The probing end of this wooden extension should be razoredged and V-shaped to ride against the shaft. Hard wood such as maple should be used. Lubricating oil should be applied to permit riding ease on the shaft.

The charts on the next pages illustrate the approximate degree of vibration which can be tolerated on machinery. The values of the first chart (by T. C. Rathbone) are based on practical data obtained from a large number of machines and are only an approximate guide. Wide variations from these values may be expected from individual machines. This chart was established for heavy rotating equipment; the vibration levels are much too excessive to be applied to precision machine tools and precision equipment. This chart should definitely not be used for such machinery.

The values on the second chart are for shipboard equipment as noted in MIL-STD-167 (SHIPS) 12/20/54.



* Frequency corresponds to RPM when dynamic imbalance is the cause of vibration



* Frequency corresponds to RPM when dynamic imbalance is the cause of vibration

IN-PLACE BALANCING

BASIC REQUIREMENTS

A. Vibration must be due to imbalance.

1. Stroboscopic lamp "freezes" or "stops" rotating part which being triggered by the vibration pickup. If necessary, the filter can be used to screen out background vibrations.

B. Means of adding or removing correction weight must be available on rotating part.

C. Means of maintaining constant speed during balancing runs is advisable.

1. Precise speed control is not required unless the system is being balanced at a mechanically resonant speed.

a. In using the filter, if the speed control is not within 1% from run to run, the filter should be reset for each run by switching to OSC and adjusting the tuner until the strobe light is in synchronism with the rotation.

b. When balancing at mechanical resonance, care should be taken that the phase shift variation with speed does not cause false readings.

GENERAL PROCEDURE

A. Place reference mark on rotating system for phase determination.

1. Keyway, scratch, etc. can be used for reference mark if first set of data is taken before equipment is shut down.

2. Place mark radially from rotating axis.

3. The end of a shaft is often the best place for the reference mark, since the position is very readily observed.

4. If there is a possibility of looseness or slippage between mating portions of a rotating assembly, mark each portion in order that it may be observed whether or not the physical relationship of the various parts of the assembly is constant throughout the job.

5. Mark can be placed at either end of a rotating assembly, but all data must be taken from one end throughout the balancing procedure.

6. If only a side view is available, use a sequence of numerals around the rotating part.

a. Numbered tape is sometimes helpful.

B. Locate points where vibration measurement will be taken.

1. Use points where sensitivity is high (high amplitude of vibration) and frequency reading steady at speed or rotating part.

a. Compromise to measure in the same direction when taking data at both ends.

2. Take measurements as close to bearings as possible.

a. If it is known that the shaft is true and has a smooth surface, it is sometimes advantageous to measure vibrations directly on the shaft.

3. On some equipment, balancing can be accomplished by measuring on a housing, foundation, support, pipe or other extension, etc.

4. Take measurements from same point or points and in same directions throughout balancing runs.

a. One point usually sufficient for each balancing plane.

b. Both vertical and horizontal measurements for each balancing planes sometimes helpful if conveniently taken.

C. Observe and record background level of vibration with apparatus shut down and not running.

1. Background level is lowest level to which equipment can be balanced.

2. If the Vibration Analyzer diagnoses the source of background vibration, correct or note for future correction.

D. Observe and record original running conditions.

1. Record amplitude in inches or mils.

2. Record relative phase angle in degrees or apparent clock position in hours.

3. Repeat original runs if (1) instability is suspected, (2) equipment appears to be running near mechanical resonance, or (3) poor speed control is suspected.

a. Check for consistency in readings.

b. Use oscillator to ensure that runs are being taken at exactly the same speed if poor speed control is being encountered.

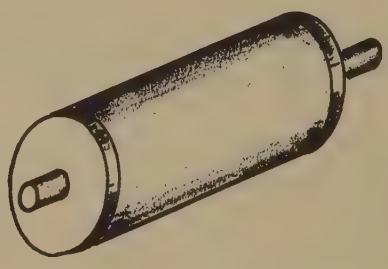
What is imbalance -

One of the most common causes of vibration in machinery is imbalance of the rotating components. This imbalance is mostly due to a heavy spot or weight for which there is no compensation on the opposite side of the rotating part. This heavy spot or weight may be caused by faulty design or faulty mechanical assembly.

The common term used to specify the degree of imbalance is ounce-inches; similar terms such as pound-inches, gram-inches, and micro-ounce-inches are sometimes used. These terms indicate the amount of weight and the distance from the center where the weight should be applied. For example, if a two-ounce weight is added to a flywheel at 5 inches from the center, the imbalance is expressed as 10 ounce-inches; if the weight is one ounce at 10 inches or 10 ounces at one inch, the result is also 10 ounce-inches. The same terms apply if a part is not mounted on its true center. For example, if a 20 pound (320 ounces) pulley is mounted two thousandths of one inch (.002") off center, the resulting imbalance is 320 x .002 = 0.64 ounce inches.

Balancing problems in production and in the field are normally classified as single-plane, two-plane, and multi-plane problems.

SINGLE PLANE



TWO PLANE

Single-plane problems are those in which the diameter of a rotating part is large as compared to its length, such as most grinding wheels, single groove pulleys, three and four bladed fans, pump impellers, flywheels, etc. Single-plane imbalance is often called static imbalance because, if it is severe enough, it can be detected by resting the part on rails and letting the heavy spot fall to the bottom; for example, when a bicycle wheel is rotated freely, the air valve (the heavy spot in this case) will fall to the bottom.

A part which is relatively long as compared to its diameter, such as an armature, a spindle, a shaft, etc., cannot be balanced in a single plane. This type of imbalance is called dynamic imbalance and is referred to as a two-plane problem. If the part is extremely long, or if the rotating speed of the part causes the weight of the heavy spot to "bend" the part, it may be necessary to balance in several planes.

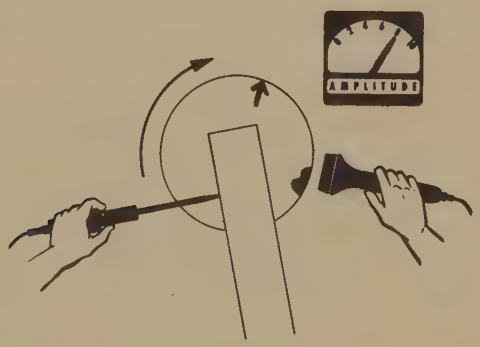
Balancing Methods -

There are two basic methods of determining the location and the weight to be added or taken-off; they are the five-step method and the vector method. In production balancing, a simpler and quicker method will apply.

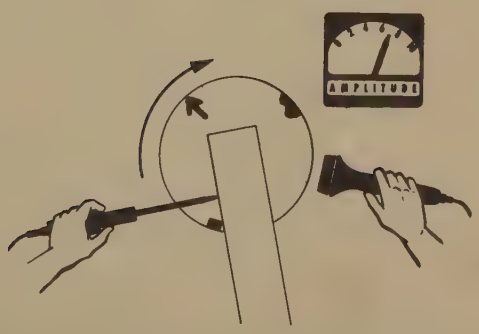
The five-step method is simple and convenient when the number of trial runs is not important and when the part is easily started and stopped. To illustrate this method, consider the case of a pulley as being the cause of predominant vibration.

Step 1 - Make a reference mark (chalk mark, keyway, paint spot, etc.) on the pulley in order to see where the mark is each time the stroboscopic lamp is triggered.

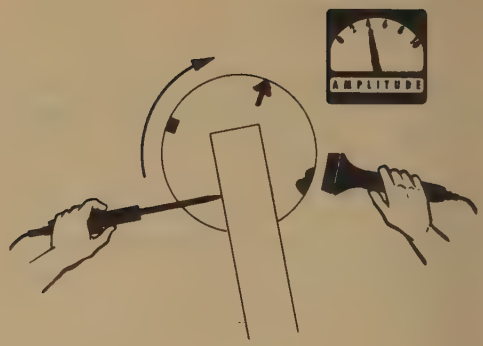
Step 2 - Place the pickup on the bearing or housing nearest the pulley and observe amplitude meter and position of mark.



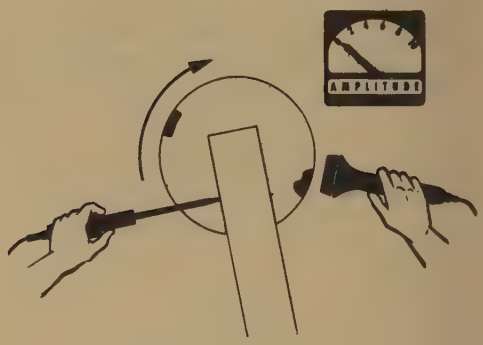
Step 3 - Add a weight to the pulley and observe the angular shift of the reference mark.



Step 4 - If the mark has moved, shift the weight in the opposite direction of the move until the mark returns to its original position or directly opposite.



Step 5 - Add or subtract weight until an acceptable degree of balance is obtained.



Rules of five-step method -

1. Always compare conditions with the first run.
2. Always move the weight in opposite direction of the shift of the mark from initial run.
3. Move the weight less than 90 degrees if vibration decreases.
4. Move the weight 180 degrees if the mark remains in the same original position and vibration increases.
5. When the mark returns to the original position, increase the weight until balance is obtained.
6. When the mark moves directly opposite its original position, reduce weight until balance is obtained.
7. Always hold the pickup at the same location and in the same direction with each run.

In cases in which it is necessary to balance a part often such as a grinding wheel, the following short cut method can be used. First the wheel is balanced using either the five-step or the vector method, noting the location of the heavy spot; then, pro-

viding the mass of the wheel is approximately the same, and the pickup is held in the same direction as in the first balancing, the heavy spot will be at the same location in relation to the reference mark each time the wheel is to be balanced. For example:

Note that the first time the wheel was balanced, the heavy spot (sometimes called the flash angle) was at 6:00 and the reference mark was at 1:00; subsequent balancings produced a different location of the reference mark but the heavy spot remained at 6:00. Consequently, to reduce the five-step method to one step, one is required to notice the original location of the heavy spot. Thereafter, this spot will always be in the same location in relation to the reference mark.

The vector method is most efficient when time and number of runs are important.

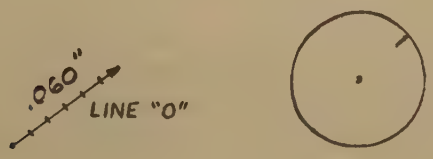
To illustrate the method, consider the case of a thin flywheel:

1. Make a reference mark as in the five-step method.

2. Place the pickup on the bearing or housing nearest the flywheel and record amplitude meter readings and position of the mark.

   Example: .060" with mark at 1:30.

3. Draw line "O" (original) on paper at the same angle as that of the mark, and with a length proportional to the amplitude.



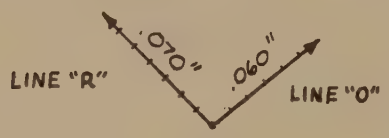
4. Add a test weight the size you think is approximately correct at any place on the flywheel.

5. On this run, record the new amplitude readings and the new position of the mark.

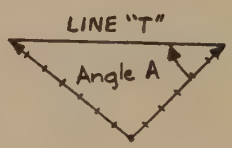
   Example: First run - .060" at 1:30.

   Second run - .070" at 10:30.

6. Add line "R" (result of adding weight to original) to the diagram with length and angle corresponding to the new reading.



7. Draw a line from the end of Line "O" to the end of line "R". This is now line "T".



The angle "A" between line "O" and line "T" tells the direction and degree that the weight should be shifted. In the above example, the weight should be moved 55 degrees clockwise from its present position. The weight is always shifted in the direction opposite the shift of the mark.

The length of the line "T" represents the effect of the test weight. The length of line "O" represents the effect of the original imbalance. The test weight should be increased or decreased according to the ratio of line "O" to line "T". In the above example, if the test weight is 10 grams, line "O" is two inches long, and line "T" is three inches long, the correct weight to be used is 10 x 2/3 = 6-2/3 grams.

8. This will not always work out on the first run because the diagrams cannot be 100% exact, and the length of the lines cannot absolutely correspond to the exact amount of imbalance. Further runs can be made and more diagrams can be drawn. Suppose the above change was made and another run taken.

   The new vibration condition is:

   First run - .060" at 1:30.

Second run - .070" at 10:30.

Third run - .010" at 6:00.

Angle "A" indicates that the weight should be shifted slightly counterclockwise (about 10^{o}) and the length ratio of line "O" to line "T" shows that the weight should be reduced slightly.

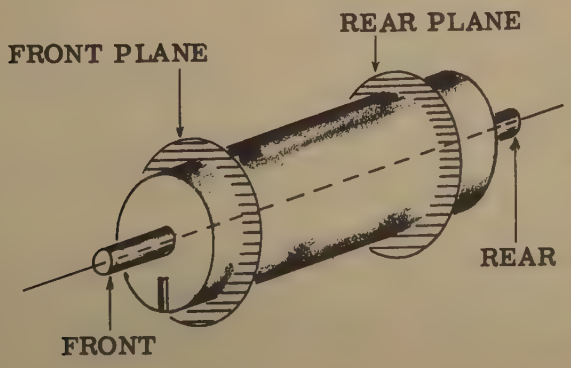
9. For finer balance, repeat this procedure, always comparing readings with the original conditions.

Two-plane balancing problems may be solved by using the same procedures as described in the previous paragraphs, and treating each end as a separate problem. However, the vector method should be used because it is the more accurate of the two in this case. When using this method, the reference mark and its shifts should always be observed at the same end of the part regardless which end is being balanced. Each step of the vector method should be followed. However, the amplitude readings must be taken at both ends of the part regardless which end is being balanced.

In some two-plane problems, after balancing one plane then the other, it may be necessary to rebalance the first plane again. This is due to cross-effect that may be introduced in the rotating part when a weight is added to one plane; this cross-effect may cause vibration at the other plane. Cross-effect is generally more severe when the correction planes are relatively close together.

In a typical two-plane problem, assume that the reference mark is the keyway and that the initial readings are:

	FRONT	REAR
Run #1	.018" at 6:00	.019" at 5:00

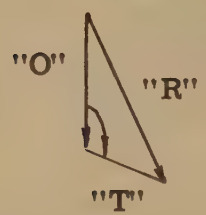


Where, as in the case above, the amplitude readings and the angle of the mark are comparable at both ends, the imbalance is roughly at the same angle and the amount similar at each end. In such a case, a single-plane correction at the center, or equal weights at each plane, (sometimes called a "static" correction) will probably remove most of the imbalance. To make such a correction, one must assume that the rotating member is fairly symmetrical and that the rigidity of the bearing mounts at each end is comparable. Assuming then that we add 10 ounce-inches in line with keyway at each plane and that the readings are:

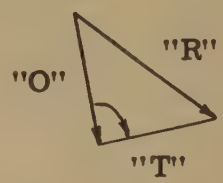
	FRONT	REAR
Run #1	.018" at 6:00	.019" at 5:00
Run #2	.021" at 5:00	.023" at 4:00

Draw a vector sketch for each plane to determine the proper moves.

FRONT



REAR



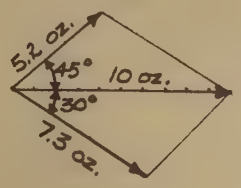
These sketches indicate that we should move the weights 100 degrees clockwise from the keyway and increase then to 15 ounce-inches at each plane. The readings now becomes:

	FRONT	REAR
Run #1	.018" at 6:00	.019" at 5:00
Run #2	.021" at 5:00	.023" at 4:00
Run #3	.005" at 6:00	.003" at 2:00

Since the reference mark now appears at different angles for each end, further attempts to statically balance the part would be useless. The next step is to consider each end as a separate balancing problem starting with the front because the amplitude is greater at that end. The corrections already made should not be disturbed; this now is a new problem. Start with run #3 as the original run.

In many two-plane balancing problems, the phase lag at each end of the system will be the same or very nearly the same. Therefore, after the angle at which the heavy spot fires the light has been determined at one end, this information may be used to locate the point on the other end at which the trial weight should be added.

There are occasions when the weight must be divided between two positions because there may be only certain places on the part on which correction can be made. In these cases, a vector sketch can be drawn to determine the amount and position of each weight. For example, suppose 10 ounce should be added at a certain point, but the only places available are at 30 degrees clockwise and 45 degrees counter-clockwise from the spot where the weight should be added. The sketch is drawn to scale as a parallelogram with the 10 ounce line as the diagonal; the length of the sides indicates the amount of weight to be added at each piece.



As seen in the above diagram, 7.3 ounces should be added at 30 degrees clockwise and 5.2 ounces should be added at 45 degrees counter-clockwise. Note here that the two weights amount to more than 10 ounces; that is normal because, when correction weights are divided, a greater weight is required than if it were placed in one location.

In balancing various types of components, temporary weights are normally used before permanent weights are attached. The only exception is in production balancing where the system has been previously calibrated by the flash-angle method to quickly determine the location and amount of balancing correction.

Typical means of applying temporary weights are:

1. Using balancing clay on the rotating part.

2. Adding bolts, nuts, or washers to through holes, tapped holes, or threaded studs.

3. Clipping weights and U-clamps (mounted in such a manner that centrifugal force helps in holding the weights.

4. Adding layers of short lengths of tape (for fine correction on very light components).

5. Adding weights in accordance with balancing provisions by the manufacturer of the equipment being balanced.

6. Fastening weights to metal baling bands strapped around the part (for cylindrical surfaces on which there is no ready means of adding weight).

After balancing has been obtained with temporary weights, these must be replaced by permanent type ones. It is very important to remember that the permanent cor-

rection must be equal in ounce-inches to the temporary weight. This is also very important when the final correction cannot be made at the same radius as the temporary weight was located. Typical means of making permanent corrections are:

1. Welding metal weights (the weight of the welding material must be taken into consideration).

2. Soldering.

3. Permanently attaching weights in accordance with provisions made by the manufacturer.

4. Adding bolts, nuts, or washers to through holes, tapped holes, or threaded studs.

5. Drilling, grinding, or filing.

6. Fastening clips or U-clamps permanently.

When balance correction is being made by drilling, grinding, or filing, it must be remembered that weight must be removed directly opposite from where the trial weight was added. In such cases where weight is removed, a shift of the reference mark may occur. In this case, the remainder of the weight should be removed in the opposite direction of the shift of the mark.

Model 600 can easily serve as the electronic brain to any IRD Dynamic Balancing Machines, thus eliminating costly duplication of instruments. No special tooling is required; simply connect the Analyzer to the machine.

MAINTENANCE

Model 600 Vibration Analyzer requires no mechanical maintenance. Tubes and wiring are the only components other than accessories that could require maintenance.

The tubes used in this Vibration Analyzer are of the ruggedized industrial type, and as a result, can be expected to give long trouble-free service. If a tube breaks, a replacement is recommended with either a ruggedized or a commercial tube. Occasionally, when tubes are replaced, recalibration will be necessary.

In the event the stroboscopic bulb emits a dull blue continuous glow rather than a blue-white flash, the bulb is continuously discharging. This discharge can be stopped by turning the analyzer off and on again. The bulb should be replaced as soon as possible. In case of any other malfunctions of the stroboscopic lamp, return the unit to the factory to be repaired.

The vibration pickup should always be returned to the factory to be repaired. Also, when returning Model 600 to the factory to be repaired, always include pickup and stroboscopic lamp so that calibration can be effected.

The following performance checks are recommended before proceeding with the major electrical maintenance procedure. They are listed to direct the trouble-shooting efforts toward the most probable source of difficulty.

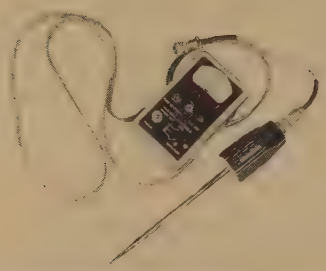
The first consideration, of course, is to make sure the power is applied to the instrument. If not, check the fuse located at the rear of the unit. A spare fuse is also located at the rear. Secondly, connect the stroboscopic lamp and cable, remove the pickup cable and make the following test.

Place the control in the OSC position with the frequency range selector on the 1.5 or 5 range; check whether or not the frequency reading can be varied using the tuning control. If a proper frequency reading is not obtained, there is difficulty in the console.

If a steady frequency reading is obtained with the control in the OSC position, depress the push-button switch to see whether the stroboscopic bult is actuated. If the bulb does not light, check the bulb by replacement. CAUTION - the power should be turned off while the bulb is being replaced. If this does not provide satisfactory operation, check the continuity of the conductors in the strob cable by resistance measurement. If a cable fault is not found, the difficulty is in the strob lamp or console, and the analyzer should be returned to the factory for repair or disassembled for a complete electronic check.

To check the operation of the amplitude meter, place the frequency range selector on the 5 position, the filter in the OUT position, and the amplitude range selector in the test position. An amplitude reading of approximately half scale (.5) and a frequency reading of 3600 should result. If an amplitude reading is not obtained, then incorrect functioning within the instrument is indicated.

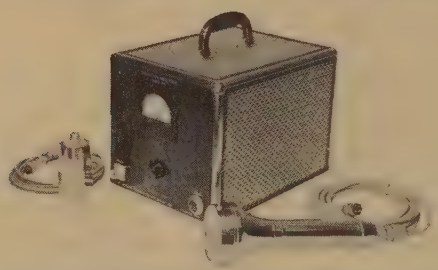
If the previous checks show satisfactory amplitude meter operation, the pickup should be connected. Proper pickup operation can be checked by the fact that the slight motion of the hand holding the pickup with filter "OUT" should cause an erratic but appreciable reading of amplitude and frequency. The amplitude range selector should be placed on the 0.1 mil range for this check. If this does not occur, failure has developed, and the pickup cable should be checked.



MODEL 305 Portable Vibration Meter

Basic function: Measuring vibration displacements (double amplitude) from micro-inches to .010 in.

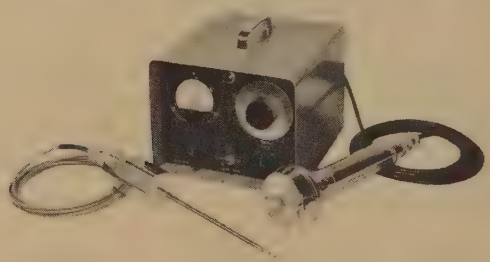
Application: Checking permissible vibration tolerances—the key to satisfactory operation on all types of machinery with rotating components.



MODEL 300 Vibration Analyzer

Basic function: Measuring vibration displacements. Dynamic and single-plane balancing.

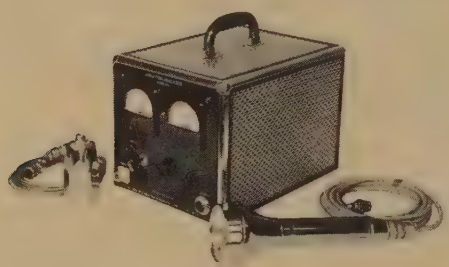
Application: Checking permissible vibration tolerances, in-place balancing of blowers, motors, impellers, etc., without costly dismantling. Operating range 600 cpm to 5000 cpm.



MODEL 311 Vibration Analyzer

Basic function: Measuring vibration displacements. Analyzing frequencies with variable filter.

Application: Checking permissible vibration tolerances. Troubleshooting and pinpointing each source of vibration.
In-place balancing without costly dismantling. Operating range 500 cpm to 5000 cpm.



MODEL 400 Vibration Analyzer

Basic function: Measuring vibration displacements and frequencies. Dynamic and single-plane balancing.

Application: Checking permissible vibration tolerances. Troubleshooting and pinpointing each source of vibration.
In-place balancing without costly dismantling.
Operating range 600 cpm to 20,000 cpm.

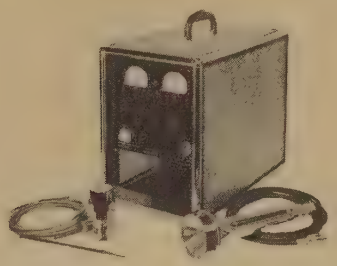
MODEL 557 Vibration Analyzer

Basic function: Measuring vibration displacements and frequencies.
Analyzing frequencies with variable filter.
Observing vibration waveform.

Application: Checking permissible vibration tolerances in jet engines and associated high speed accessories. Troubleshooting and pinpointing each source of vibration. Operating range 600 cpm to 300,000 cpm.

DYNAMIC BALANCING EQUIPMENT

MODEL 652 Vibration Analyzer



Basic function: Measuring vibration displacements and frequencies.
Dynamic and single-plane balancing.

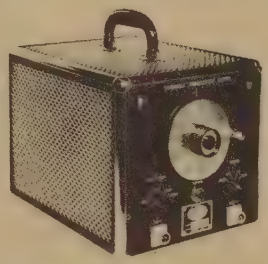
Application: Checking permissible vibration tolerances. Troubleshooting and pinpointing each source of vibration.
In-place balancing without costly dismantling. Operating range 500 cpm to 40,000 cpm.

MODEL 752 Vibration Analyzer

Basic function: Measuring vibration displacements and frequencies. Dynamic and single-plane balancing.
Tuning to specific frequencies.

Application: Checking permissible vibration tolerances in power house machinery. Troubleshooting and pinpointing each source of vibration. In-place balancing without costly dismantling. Operating range 500 cpm to 10,000 cpm.

MODEL 1065 Continuously Variable Filter



Basic function: Analyzing frequencies in conjunction with any IRD vibration analyzer.

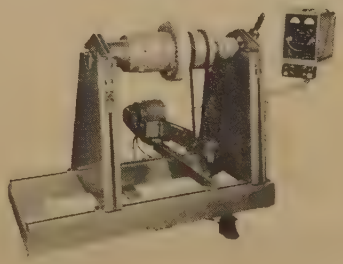
Application: Tuning to various frequencies in machinery in order to study each component as a separate part without dismantling.

MODEL 600 Vibration Analyzer

Basic function: Measuring vibration displacements and frequencies.
Analyzing frequencies with variable filter.
Dynamic and single-plane balancing.

Application: Checking permissible vibration tolerances. Troubleshooting and pinpointing each source of vibration. In-place balancing without costly dismantling. Operating range 450 cpm to 160,000 cpm.

MODEL 102 Dynamic Balancing System



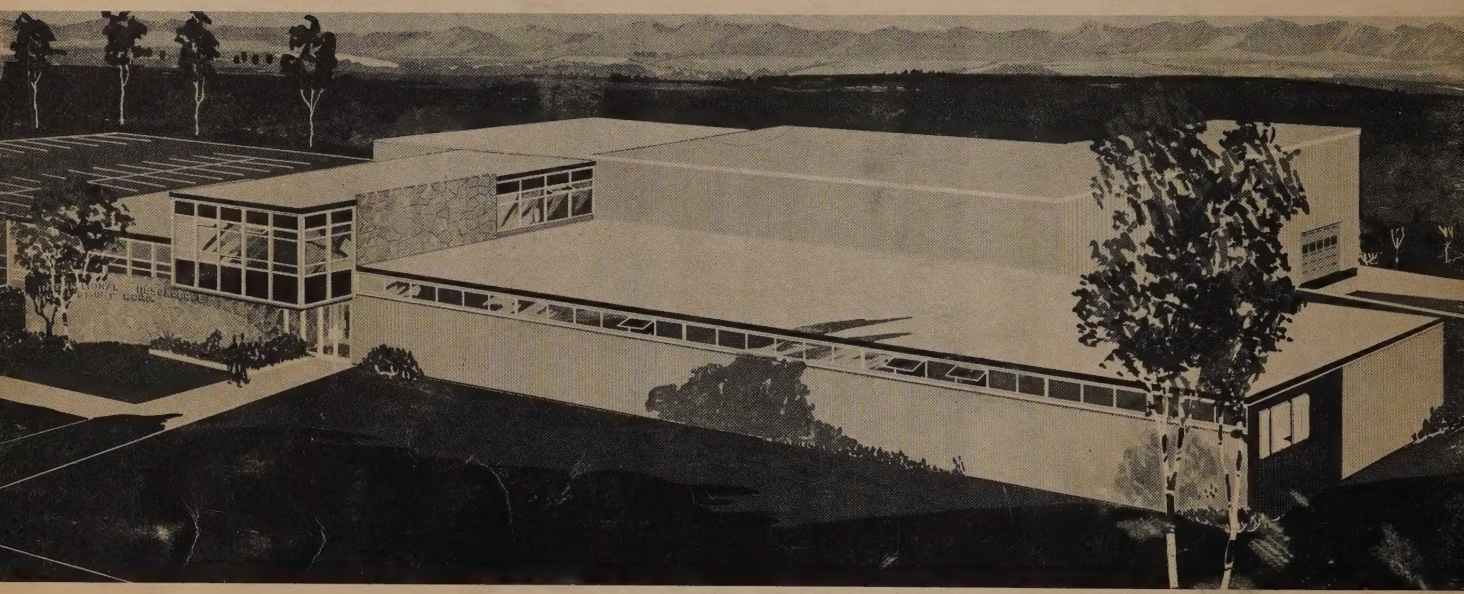
Basic function: Dynamic and single-plane balancing.

Application: Balancing disassembled components such as rotors, shafts, flywheels, etc. All IRD Vibration Analyzers used in conjunction with the dynamic balancing system are readily disconnected to afford portable vibration analyzing and in-place balancing.

NOTES

Vibration Analyzer Serial No._____

Pickup Serial No._____



IRD

Research & Development Center
Worthington, Ohio

Litho in U.S.A.